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tested by its grittiness, which is due to inorganic crystals, and rhubarb should contain a high per cent. of inorganic matter.

Other uses might be enumerated and given in this list, and perhaps some of them are of more importance than those mentioned, but sufficient has been said to show that they are probably of some practical value to man. It is hoped that this article will induce other investigators to take up this subject and find, if possible, their exact use in the economy of the plant.

The time is probably not far distant when we will know more about microscopical crystals in plants, and for that time we must all wait, each investigator endeavoring to do his best.

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ON THE ORIGIN OF THE LAC.[1]

BY J. M. STILLMAN.

DURING the course of an examination of a product from Arizona, apparently identical with the gum-lac from India, I had occasion to consult various works touching on the origin of this interesting product.

The statements met with were in many cases contradictory, and the most usual statement so directly opposed to what appears to me, from a careful examination of the deposit and of the evidence on the subject, to be the truth, that I cannot refrain from at least suggesting what seems to me to be the true state of affairs. At the same time I wish to state, that as far as the lac insect is concerned, I have not been able to find sufficient data regarding its anatomy and life-history to enable me to touch upon some very interesting points in connection with the subject. Nor am I certain that the questions here considered have not been thoroughly discussed by previous investigators, but if so, the current chemical literature, encyclopædias and some of the natural history treatises have overlooked such work, so that there has crept into the literature a statement with regard to the origin of the gum-lac which I think is an incorrect one. This is, that the gum-lac is an *exudation* caused by the puncture of the lac insect *(Coccus lacca)*.

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[1] This paper was read before the California Academy of Sciences, April 19, 1880.

This is stated in such standard works as "Muspratt's Chemistry" (even in the late German edition), Wurtz's "Dictionnaire de Chimie," "Johnson's Encyclopædia," &c., and in various text-books on chemistry, and various works on natural history accessible to me. "Chamber's Encyclopædia also asserts the same fact by saying that the insects "entomb themselves in a mass of matter which oozes from small punctures made in the twigs of the tree," but also adds, "As we have no strictly analogous resin from the vegetable kingdom, *not even from* the lac-bearing trees, it may be assumed that the *juices of the trees* are somewhat altered by the insects."

Watt's "Dictionary of Chemistry," on the other hand, says: "Lac is the product of the *Coccus lacca*, which deposits its eggs on the branches of a tree called Bihar in Assam and other parts of India. It appears designed to answer the purpose of defending the eggs from injury and affording food for the maggots in a more advanced state. It is formed into cells finished with as much art and regularity as in the honey-comb, but differently arranged."

This statement is not to be accepted entirely, I think, but in so far as it states that the lac is the product of the insect rather than of the tree, I think it is correct, and it is this thesis that I wish here to maintain.

Let me first state briefly all that I feel confident of regarding the life-history of the *Coccus lacca* of India. The lac insect, like many other insects of its kind, lives and dies in the same spot. The young insect, after emerging from its hatching place in the body of the mother, crawls off as an extremely minute bug of a bright red color. It very soon attaches itself to the branch, loses its legs, antennæ, &c., its sides expand and it becomes fixed to the branch like a minute scale bug. Here it grows and lives upon the juices of the twig which it sucks from minute punctures in the bark. If it be a female, and I shall take cognizance here only of the female insect, as it grows older it forms its eggs, and the entire insect develops into a shapeless sac enveloping these eggs. Within this sac is developed at the same time a purple-red gelatinous mass which contains the eggs and perhaps serves as food for the young insects. By this time, also, the numerous sacs are entirely enveloped in a heavy mass of the lac-resin. The cellular structure of the latter is caused by the soft sacs of the females enclosed in the hard resin. When the young are hatched, they bore a hole through the back of the mother-sac and through the resinous envelope and escape, fix themselves to new portions of the plant and the life-history begins again.

Now, although I am by no means confident that the Coccus which forms our Arizona lac is identical with the *Coccus lacca*, yet I think that I can show that the resemblance is sufficiently close to enable a course of reasoning on this insect to apply to the Indian species as well. In the first place the very great chemical similarity of the Arizona gum to the Indian, as shown at a meeting of the California Academy, is a presumption to this effect. In the next place, the coarse cellular structure of the resin, the enclosed sacs with the eggs and purple juice, formed in the Arizona product and agreeing with the descriptions of the India lac, are another set of facts strongly confirmatory. Lastly, the specimens of lac from Arizona with the holes bored in it by the escaping insects, furnish additional evidence of close agreement. Very recently also I have received from Mr. J. A. Culbertson, of Arizona, specimens of the young insects affixed to the twigs. They are minute scale-bugs of a red color, with indistinct markings across the back. In size I should roughly estimate them at one-fiftieth of an inch in length and half that in width, though some are even smaller. No doubt could exist but that they belong to the Coccidæ, and that they are very similar in development and life-history to the *Coccus lacca*. Hence I think that any general deductions from examination of the Arizona lac will apply equally well to the India product, especially as all descriptions of the products of the insect—lac-dye and lac-resin—seem to coincide.

We notice first that resin is developed only by the action of this insect. No similar product can be obtained from the plant by other means. This is stated of the India lac in the sentence above quoted from "Chambers' Encyclopædia." Eye-witnesses say, that the Arizona lac also does not occur wherever the plant, upon which it grows, is found, but only in particular regions or patches. In the second place the gum-lac of India occurs on no less than five trees, *Ficus religiosa*, *Ficus indica*, *Rhamnus jujuba*, *Croton lacciferum*, *Butea frondosa*, and that from Arizona on two plants, the *Larrea mexicana* and *Acacia greggi*. These plants are not related for the most part, and do not afford the gum except under the influence of the insect.

In explanation of these facts we have two alternatives to choose from. First, the gum is an exudation from the twig, excited by the puncture of the Coccus; it flows out, envelops the insects, hardens and forms the gum-lacs; or, second, *that the gum is the elaboration of the insect itself.*

The first explanation is the one usually given, the second one appears to me the true one, and the following facts and considerations appear to me to sustain this view:

1. The gum-lac is not simple, like most vegetable resins, but is composed of resins soluble in alcohol, wax and gluten, or substances resembling gluten. Such a complex substance might be expected from an animal secretion.

2. The resin, as far as known, possesses the same general composition and properties independent of the species of plant, whence it is derived, since no specific difference is given for any of the seven India varieties, and the two Arizona sorts have probably the same general composition. The kind of plant and the character of its juices undoubtedly have a general influence, inasmuch as the sap of some plants would not support the life of the insect nor furnish it its necessary materials for the elaboration of its products.

3. If the resin were an exudation from the plant, simply induced by the puncture, we should expect to find this resin more or less collected into globules, drops, or masses independent of the immediate presence of the insect. In my examination I could find no particle of resin which did not form a bounding wall to one or more of these cells occupied by the egg-sacs.

The only places, where the resin appeared solid and thick, was in the spaces between three or more contiguous cells, as if the sacs had, by their united secretions, filled up the small room between them. In some specimens what appeared to be a small drop of resin on the bark, where a small insect had covered its dome-shaped body with a layer of resin, was as thin-walled as the shell of a mustard seed. In such a case we are called upon to suppose that a flow of resinous juices starts from below the insect, passes up over its body and nowhere else, and covers it with an even layer of resin. This is to me a difficult conception.

On the other hand, it is easy to conceive how the insect simply feeding on the juices from below, and secreting this resinous substance from its body, could build such a shell of resin.

4. By careful examination of bark and wood, no puncture or abrasion could be detected at all adequate to account for such a *spontaneous flow* of the sap of the plant, as would produce the amount of resin present. This examination was repeated with the assistance of Prof. Joseph Le Conte, who concurred fully in the conclusion arrived at.

All these facts, so inexplicable on the exudation theory, appear to me to be readily explained on the basis of the insect origin of the gum. The insect fixes itself to a spot on the bark where it lives and dies. For its sustenance it is dependent on the sap of the plant. Certain plants are adapted to this purpose, others are not. The juices sucked up and absorbed by the insect serve as its food, and at the same time as material, from which is elaborated the resinous envelope, destined to serve as a protection for the eggs and larvæ. This resinous substance may be exuded from the entire surface of the insect, or from particular organs or glands; I am in no position to pursue this point, interesting as it is. This elaboration thickens as the insect grows older, and as the insects live in close proximity they become crowded and distorted, and the spaces between them compactly filled with their united elaborations, so that the result is as we see it, a resinous mass of coarse, irregular, cellular structure, with the egg-sac filling the cell, or, after the specimen is dried or the young escaped, with the shrunken remains of sac and eggs in the cell.

This explains the occurrence of practically the same resin on various plants—the form and structure of the resin—that it surrounds the sacs on all sides perfectly, but does not run off along the bark of the twig nor collect into solid drops or masses—a fact difficult to explain on the simple exudation theory. It also gives a definite meaning to the "alteration" of the juice by the insect referred to in "Chambers' Encyclopædia."

Whether the lac is to be considered as an excretion or secretion is very much a matter of definition. If by secretion we mean a definite substance elaborated by the organism for a definite purpose, this would appear to be a true secretion. On the other hand, once secreted it probably exerts no further internal function in the organism, and is in so far an excretion. In the same sense, hair, nails, epidermis, etc., continually discarded by the organism, might be considered excretions. However we may regard it, it is probably a normal product of the vital activity of the lac insect.

A somewhat striking objection against this theory is, that it is against analogy, that a well-marked resin should be the product of animal life. But so also is the production of *wax* by the bee against the same analogy, and yet it has been proven that bees confined to an exclusive diet of sugar will produce wax formed by their own vital processes, and any philosophical distinction between *wax* and *resin* in *this* particular would, I think, be difficult to establish.

In conclusion, I would again reiterate that I am by no means certain that the question of the origin of the lac has not been settled by observers more directly interested in natural history, but if so, our chemists and encyclopædists have been slow to find out the facts, and our most recent authorities, with few exceptions, adhere to the exudation theory. If this communication has the effect of bringing to notice previous work, or gives rise to more complete investigations in the future, it will be as much as I can expect from it.

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BOTANIZING ON THE COLORADO DESERT.

BY EDWARD LEE GREENE.

I.

IN February of 1877, by way of the stage road between San Diego and Fort Yuma, I made a little expedition across the interesting region above named. A desert is not naturally supposed to be the most eligible locality, nor midwinter the best season for making botanical excursions, yet seldom has a week's recreation of that kind given me more satisfaction than that upon which I have preserved the following notes:

In passing from west to east across Southern California, the